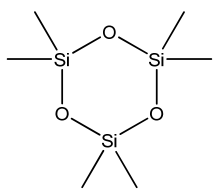
Cyclosiloxanes

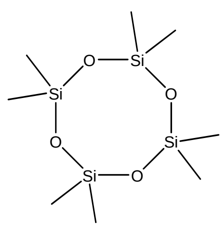
Materials for the December 4-5, 2008 Meeting of the California Environmental Contaminant Biomonitoring Program (CECBP) Scientific Guidance Panel (SGP)

Agenda Item: "Consideration of Potential Designated Chemicals"

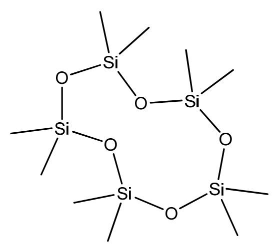
The siloxanes are chemicals that have a backbone structure of silicon and oxygen atoms, alternating in occurrence, and have hydrocarbon groups attached to the silicon side chain. In the cyclosiloxanes, the silicon-oxygen atoms are singly bonded and form a ring. Some widely used cyclosiloxanes are: hexamethylcyclotrisiloxane (D3), octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5) and dodecamethylcyclohexasiloxane (D6).



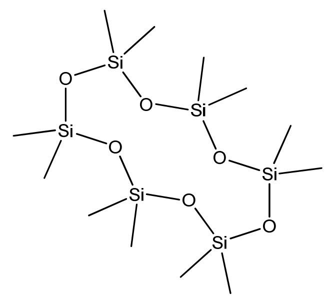
D3



D4



D5



D6

The cyclosiloxanes are used in the manufacture of silicones, in combination or alone in personal care products, and as carriers, lubricants and solvents in a variety of commercial applications. They occur in environmental media, especially in sewage sludge. In studies conducted by the Nordic countries, D5 was the dominant siloxane in all environmental matrices sampled except for air, where D4 dominated. Certain siloxanes are persistent in the environment, resisting oxidation, reduction, and photodegradation. Varying information exists on the susceptibility of siloxanes to hydrolysis. Some will be metabolized and the metabolites (hydroxylation metabolites) are expected to be found in blood and urine.

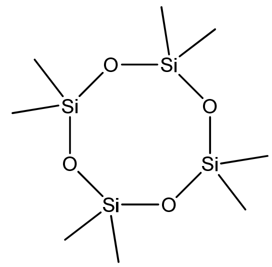
Because cyclosiloxanes are ubiquitous, special care is required to avoid the risk of contamination of samples during sample collection, storage and analysis. Evaporation or loss of the volatile siloxanes is also an analytical consideration. D3 is very volatile and subject to analytical difficulties. The necessary equipment to perform the analysis is available in the laboratory; however, method development and standards will be needed.

<u>Need to assess efficacy of public health actions:</u>

Cyclosiloxanes appear to be persistent and to have long half-lives in people. The weak estrogenic activity of D4, in combination with its long half-life, poses potential concerns for exposed individuals. While studies have not shown D5 to be estrogenic, it nonetheless increased uterine tumors in animal studies. In addition, there are potential concerns related to effects of D5 on the neurotransmitter dopamine and the hormone prolactin. Cyclosiloxanes are being touted as safer alternatives for a variety of uses, including D5 as a substitute for perchloroethylene in dry cleaning. It would be important to know if substitutes for existing chemicals are accumulating in the environment. Biomonitoring cyclosiloxanes could detect rising levels in humans, which would be of concern because of the evidence of biological effects associated with these chemicals. These measurements would be an important tool for evaluating the public health efficacy of substituting cyclosiloxanes as less toxic alternatives for other chemicals. This is an especially important question given new efforts under the California Green Chemistry Initiative to encourage the use of safer substitutes.

Additional information on D4, D5 and D6 follows.

Octamethylcyclotetrasiloxane (D4) [CAS No. 556-67-2]



Exposure or potential exposure to the public or specific subgroups:

D4 is an intermediate in the manufacture of polydimethylsiloxanes, which are used in industrial and consumer (personal care and household products) applications including fermentation processes, instant coffee production, paper coatings and sizing, diet soft drinks, waste yeast tanks, food washing solutions, adhesives, textiles, de-asphalting, boiler treatments, detergents, cleaning solutions, surfactants, cosmetic products, and polishes. In combination with D5, D4 is used in the cosmetics and toiletries industry under the trade name cyclomethicone. Annual U.S. import/production volume of D4 was between 100 and 500 million pounds in 2002 (U.S. EPA 2002). D4 has been detected in wastewater streams (Mueller et al. 1995). Human exposures can occur when personal care products, cosmetics and other consumer products containing this substance are used, and potentially could also occur through environmental exposures (HSDB). Horii and Kannan (2008) used measurements of D4 in consumer products to estimate the daily exposure rate for women in the United Sates (ages 19-65) to D4 from the use of personal-care products as approximately 1 milligram (mg)/day.

Known or suspected health effects:

D4 animal toxicity studies found changes in organ weights (Burns-Naas et al. 2002, McKim et al. 2001a, He et al. 2003), induction of hepatic drug metabolizing enzymes (McKim et al. 1998), and adverse effects on reproductive health and function, including weak estrogenic effects (Stump et al. 1997 and 1999, He et al. 2003, Quinn et al. 2007a and 2007b, Siddiqui et al. 2007, Meeks et al. 2007; McKim et al. 2001b). D4 exposure has also been associated with the development of benign uterine tumors (adenomas) in rats (Plotzke et al. 2000). The acute LD50 of 6-7 g/kg indicates that D4 is acutely non-toxic (Lieberman et al. 1999).

Potential to biomonitor:

Physical and chemical properties:

Vapor pressure: 1.05 mmHg at 25 $^{\circ}$C.

Water solubility: 5.0×10^{-3} mg/L (5 ppm) at 25 $^{\circ}$C.

Octanol/water partition coefficient: Log K_{ow} 5.1

Bioaccumulation: Bioconcentration factor (BCF) 12,400 L/kg

Persistence: Atmospheric degradation $t_{1/2}$ 13 days. Virtually no mobility in soil (K_{oc} 14,000) but some volatilization from moist and dry soil surfaces expected. If released into water, D4adsorbs to suspended solids and sediment and estimated volatilization $t_{1/2}$ 1.8 hours (river); 6.8 days (lake); 120 days (pond).

Past biomonitoring studies: The national survey of human adipose tissue conducted in 1982 analyzed 46 composite samples and qualitatively found D4 in 21 samples (U.S. EPA. 1987). Flassbeck et al. (2001) analyzed plasma and blood of women exposed to silicone gel filled implants (n = 14) and found that many years after the removal of ruptured silicone implants, D4 was present in the range of 14-50 ng/mL in plasma and 79-92 nanograms/milliliter (ng/mL) in blood. D4 was not detectable in plasma or blood of women without implants. In 3 women with silicone gel-filled implants, D4 was the most abundant siloxane found and was present at levels ranging from 11.9 - 1,300 nanograms/gram (ng/g) depending on the woman and the type of tissue sampled; no siloxanes were detected in control breast tissue samples (Flassbeck et al. 2003).

Availability of analytical methods: Hexane is used for extraction. The clear layer of the extract may be ready for High Resolution GC/ High Resolution MS (HRGC/HRMS). Metabolite analysis may be important. Several studies have measured cyclic siloxanes in human and rodent tissues, using gas chromatography coupled with an atomic emission detector (GC-AED) or mass spectrometric detector (GC-MS) (Kala et al. 1997; Flassbeck et al. 2001, 2003; Lykissa et al. 1997).

Availability of adequate biospecimens: Plasma and blood specimens. Highly lipophilic, metabolized by the liver, eliminated by exhalation and excretion – rates depend on the route of exposure (He et al. 2003). Major metabolites in rodents are dimethylsilanediol and methylsilanetriol (Varaprath et al. 1999, 2000).

Incremental analytical cost: Can be bundled with other cyclosiloxanes.

References:

Burns-Naas LA, Meeks RG, Kolesar GB, Mast RW, Elwell MR, Hardisty JF, Thevenaz P. 2002. Inhalation toxicology of octamethylcyclotetrasiloxane (D4) following a 3-month nose-only exposure in Fischer 344 rats. Int J Toxicol. Jan-Feb;21(1):39-53.

Flassbeck D, Pfleiderer B, Grumping R, Hirner AV. 2001. Determination of low molecular weight silicones in plasma and blood of women after exposure to silicone breast implants by GC/MS. Anal Chem. 73(3):606-11.

Flassbeck D, Pfleiderer B, Klemens P, Heumann KG, Eltze E, Hirner AV. 2003. Determination of siloxanes, silicon, and platinum in tissues of women with silicone gel-filled implants. Anal Bioanal Chem. 375(3):356-62.

HSDB (Hazardous Substances Data Bank). Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

He B, Rhodes-Brower S, Miller MR Munson AE., Germolec DR., Walker VR., Korach KS., Meade BJ. 2003. Octamethylcyclotetrasiloxane exhibits estrogenic activity in mice via ERalpha. Toxicol Appl Pharm 192:254–261.

Horii Y. and Kannan K. 2008. Survey of organosilicone compounds, including cyclic and linear siloxanes, in personal-care and household products. Arch Environ Contam Toxicol. 55(4):701-710.

Kala SV, Lykissa ED, Neely MW, Lieberman MW. 1998. Low molecular weight silicones are widely distributed after a single subcutaneous injection in mice. Am J Pathol. Mar;152(3):645-9.

Lieberman MW, Lykissa ED, Barrios R, Ou CN, Kala G, Kala SV. 1999. Cyclosiloxanes produce fatal liver and lung damage in mice. Environ Health Perspect. Feb;107(2):161-5.

Lykissa ED, Kala SV, Hurley JB, Lebovitz RM. 1997. Release of low molecular weight silicones and platinum from silicone breast implants. Anal Chem.69(23):4912-6.

McKim Jr., J.M., Wilga, P.C., Kolesar, G.B., Choudhuri, S., Madan, A., Dochterman, L.W., Breen, J.G., Parkinson, A., Mast, R.W., Meeks, R.G., 1998. Evaluation of octamethylcyclotetrasiloxane (D4) as an inducer of rat hepatic microsomal cytochrome P450, UDP-glucuronosyltransferase, and epoxide hydrolase: a 28-day inhalation study. Toxicol. Sci. 41:29–41.

McKim, J. M., Jr., Kolesar, G. B., Jean, P. A., Meeker, L. S., Wilga, P. C., Schoonhoven, R., Swenberg, J. A., Goodman, J. I., Gallavan, R. H., and Meeks, R. G. 2001a. Repeated inhalation exposure to octamethylcyclotetrasiloxane produces hepatomegaly, transient hepatic hyperplasia, and sustained hypertrophy in female Fischer 344 rats in a manner similar to phenobarbital. Toxicol. Appl. Pharmacol. 172:83–92.

McKim JM Jr, Wilga PC, Breslin WJ, Plotzke KP, Gallavan RH, Meeks RG. 2001b. Potential estrogenic and antiestrogenic activity of the cyclic siloxane octamethylcyclotetrasiloxane (D4) and the linear siloxane hexamethyldisiloxane (HMDS) in immature rats using the uterotrophic assay. Toxicol Sci. 63(1):37-46.

Meeks RG, Stump DG, Siddiqui WH, Holson JF, Plotzke KP, and Reynolds VL. 2007. An inhalation reproductive toxicity study of octamethylcyclotetrasiloxane (D4) in female rats using multiple and single day exposure regimens. Reproductive Toxicology 23:192-201.

Mueller, JA., Di Toro DM., and Maiello JA. 1995. Fate of Octamethylcyclotetrasiloxane (OMCTS) in the atmosphere and in sewage treatment plants as an estimation of aquatic exposure. Environ. Toxicol. Chem. 14:1657–1666.

OEHHA (2007). Toxicity Data Review: Decamethylcyclopentasiloxane (D5). September 13, 2007. Available at http://www.arb.ca.gov/toxics/dryclean/oehhad5review.pdf.

Plotzke KP, Crofoot SD, Ferdinandi ES, Beattie JG, Reitz RH, McNett DA, Meeks RG. 2000. Disposition of radioactivity in fischer 344 rats after single and multiple inhalation exposure to [(14)C]Octamethylcyclotetrasiloxane ([(14)C]D(4)). Drug Metab Dispos. Feb;28(2):192-204.

Quinn A., Dalu A., Meeker LS., Jean PA., Meeks RG., Crissman JW., Gallavan RH., Plotzke KP. 2007a. Effects of octamethylcyclotetrasiloxane (D4) on the luteinizing hormone (LH) surge and levels of various reproductive hormones in female Sprague-Dawley rats. Reproductive Toxicology 23:532–540.

Quinn AL, Regan JM, Tobin JM, Marinik BJ, McMahon JM, McNett DA, Sushynski CM, Crofoot SD, Jean PA, Plotzke KP. 2007b. In vitro and in vivo evaluation of the estrogenic, androgenic, and progestagenic potential of two cyclic siloxanes. Toxicol Sci. Mar;96(1):145-53.

Siddiqui WH, Stump DG, Plotzke HP, Holson JF, Meeks RG. 2007. A two-generation reproductive toxicity study of octamethylcyclotetrasiloxane (D4) in rats exposed by whole-body vapor inhalation. Reprod Toxicol. 23:202-15.

Stump DG, Reynolds VL. 1997. An inhalation range-finding reproductive toxicity study of octamethylcyclotetrasiloxane (D4) in male rates, document control no. 86980000062. Washington, DC: Toxic Substance Control Act Public Docket Office, Environmental Protection Agency.

Stump DG, Reynolds VL. 1999. An inhalation reproductive toxicity study of octamethylcyclotetrasiloxane (D4) in female rats using multiple and single-day exposure regimens, document control no. 86990000058. Washington, DC: Toxic Substance Control Act Public Docket Office, Environmental Protection Agency.

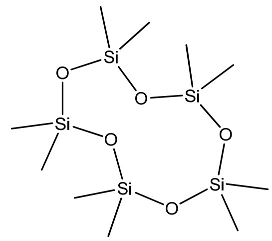
U.S. Environmental Protection Agency (U.S. EPA). 1987. Broad Scan Analysis of the FY82 National Human Adipose Tissue Survey Specimens. EPA-560/5-86-035, December 1986; Characterization of HRGC/MS Unidentified Peaks from the Analysis of Human Adipose Tissue. EPA-560/5-87-002A, May.

U.S. Environmental Protection Agency (U.S. EPA)., 2002. Non-Confidential Inventory Update Reporting Production Volume Information. Toxic Substances Control Act (TSCA) Inventory. Available at: http://www.epa.gov/oppt/iur/tools/data/2002-vol.htm.

Varaprath S, Slayers KL, Plotzke KP, Nanavati S. 1999. Identification of metabolites of octamethylcyclotetrasiloxane (D4) in rat urine. Drug Metab Dispos. 27(11):1267–73.

Varaprath S, Seaton M, McNett D, Cao L, Plotzke KP. 2000. Quantitative determination of octamethylcyclotetrasiloxane (D4) in extracts of biological matrices by gas chromatography-mass spectrometry. Int J Environ Anal Chem. 77(3):203–19.

Decamethylcyclopentasiloxane (D5) [CAS No. 541-02-6]



Exposure or potential exposure to the public or specific subgroups:

D5 is used for industrial applications (silicone fluids and elastomers) and in a wide range of consumer products (cosmetics and toiletries). D5 is used as a dry cleaning agent, and has been marketed as a safer alternative to perchloroethylene. In combination with D4, D5 is used in the cosmetics and toiletries industry under the trade name cyclomethicone. U.S. production/import volume of D5 was between 100 and 500 million pounds in 2002 (U.S. EPA 2002). D5 has been detected in indoor and outdoor air (U.S. EPA 1992), in drinking water (Lucas 1984), in sediment (Norden 2005), and in emissions from urethane cushions (Shaeffer et al. 1996). D5 has also been detected in fish and other aquatic organisms (Mait 2005, Norden 2005). Horii and Kannan (2008) estimated total daily exposure to D5 from personal-care and consumer products in women (ages 19-65) in the United States as 233 milligrams (mg)/day.

Known or suspected health effects[1]:

D5 has been shown to cause uterine endometrial adenocarcinomas in female rats (Dow Corning, 2005). D5 also has adverse health effects on the reproductive system, adipose tissue, bile production, and the immune system through its effects on prolactin, and it has the potential to cause adverse effects on the nervous system because of its influence on the neurotransmitter dopamine (OEHHA 2007). In contrast to D4, D5 has not been shown to have estrogenic effects (OEHHA 2007).

Potential to biomonitor:

Physical and chemical properties:

Water solubility 0.017 – 0.05 mg/L at 25°C.

Vapor pressure 0.2 torr (mm Hg) at 25°C.

Octanol/water partition coefficient: Log K_{ow} = 5.2 – 5.71.

Bioaccumulation: Bioconcentration factor (BCF), bioaccumulation factor > 5,000 (Environment Canada 2007).

Persistence: D5 partitions into air, water, soil, and sediment, but mostly ends up in soil and sediment (Environment Canada, 2007). D5 half-life in air is 6.9 days (Atkinson 1989). The probability that D5 will biodegrade in water or soil is "essentially zero" according to Environment Canada (2007). An environmental monitoring study in Nordic countries found D5 to be the dominant cyclosiloxane in fish livers and marine mammals (Norden 2005). Animal experiments have shown that unchanged D5 is persistent in a "variety of tissues" for "extended periods of time;" the half-life in humans is measured in weeks, and "D5 may take a year to reach

[1] Summarized from 2007 OEHHA toxicity data review on D5

steady state in fat tissue" (OEHHA 2007). OEHHA (2007) concluded that D5 "could accumulate in the environment, may bioconcentrate, and is a persistent substance." Environment Canada (2007) concluded that D5 meets the persistence criteria for soils, sediments, and water. [2]

Past biomonitoring studies: A 1982 national survey of human adipose tissue found D5 in 28 of 46 people sampled (U.S. EPA 1987). Kaj et al. (2005) detected D5 levels as high as 4.5 micrograms/liter (µg/L) in human breast milk samples in Sweden. Flassbeck et al. (2001) showed an increase in the amount of low molecular weight cyclic siloxanes in blood of women with silicone breast implants, even several years after the removal of ruptured silicone implants [D5 28 ng/ml detected in one patient]. D5 was not detectable in plasma or blood of women without implants. Flassbeck et al. (2003) found levels of D5 as high as 637±100 ng/g (~637 ppb) in the fat tissue of one woman who had a silicone gel-filled breast implant; no siloxanes were detected in control breast tissue samples.

Availability of analytical methods: Hexane is used for extraction. The clear layer of the extract may be ready for High Resolution GC/ High Resolution MS (HRGC/HRMS) to test for the parent compound which has been detected in human adipose tissue and breast milk.

Availability of adequate biospecimens: Plasma and blood. The metabolites in rat urine are methyl dimethylsilanediol [$Me_2Si(OH)_2$] and methylsilanetriol [$MeSi(OH)_3$] (Varaprath et al. 1999). No human data reported.

Incremental analytical cost: Can be bundled with other cyclosiloxanes.

References:

Atkinson R. 1989. Kinetics and mechanisms of the gas-phase reactions of the hydroxyl radical with organic compounds. Journal of Physical and Chemical Reference Data, Monographs & Supplements, Monograph No. 1. American Chemical Society; American Institute of Physics for the National Institute of Standards and Technology. Washington, DC, New York, NY.

Dow Corning Corporation. 2005. Decamethylcyclopentasiloxane: A 24-month combined chronic toxicity and oncogenicity whole body vapor inhalation study in Fischer-344 rats. Dow Corning Report No. 2005-1000-54953. 4062.

Environment Canada. 2007. Existing Substances Evaluation. Substance Profile for The Challenge. Decamethylcyclopentasiloxane (D5). CAS No. 541-02-6. Available at: http://www.ec.gc.ca/substances/ese/eng/challenge/batch2/batch2_541-02-6.cfm.

Flassbeck D, Pfleiderer B, Grumping R, Hirner AV. 2001. Determination of low molecular weight silicones in plasma and blood of women after exposure to silicone breast implants by GC/MS. Anal Chem. 73(3):606-11.

Flassbeck D, Pfleiderer B, Klemens P, Heumann KG, Eltze E, Hirner AV. 2003. Determination of siloxanes, silicon, and platinum in tissues of women with silicone gel-filled implants. Anal Bioanal Chem. 375(3):356-62.

Horii Y. and Kannan K. 2008. Survey of organosilicone compounds, including cyclic and linear siloxanes, in personal-care and household products. Arch Environ Contam Toxicol. Apr 29. [Epub ahead of print]..

[2] As set out in the 2000 Government of Canada Persistence and Bioaccumulation Regulations.

HSDB (Hazardous Substances Data Bank). Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Kaj L, Andersson J, Palm Cousins A, Remberger M, Ekheden Y, Dusan B, and Brorström-Lundén E. 2005. Results from the Swedish National Screening Programme 2004: Subreport 4:Siloxanes. IVL Swedish Environmental Research Institute.

Lucas, SV. 1984. GC/MS analysis of organics in drinking water concentrates and advanced waste treatment concentrates. Vol. 1. Analysis results for 17 drinking water and 16 advanced waste treatment and 3 process blank concentrate. EPA-600/1-84-020A. (NTIS P85-128221). Columbus, OH. Columbus Labs. Health Effects Research Laboratory

Mait RB. 2005. Letter dated October 10 to USEPA re: Notification of Substantial Risk; Detection of decamethylcyclopentasiloxane and octamethylcyclotetrasiloxane in the tissue of fish from the Rhine River in German, as referenced in OEHHA 2007.

Norden. 2005. Siloxanes in the Nordic Environment. TemaNord 2005:593. Nordic Council of Ministers, Copenhagen. Available at http://www.norden.org/pub/miljo/miljo/uk/TN2005593.pdf.

OEHHA (2007). Toxicity Data Review: Decamethylcyclopentasiloxane (D5). September 13, 2007. Available at http://www.arb.ca.gov/toxics/dryclean/oehhad5review.pdf.

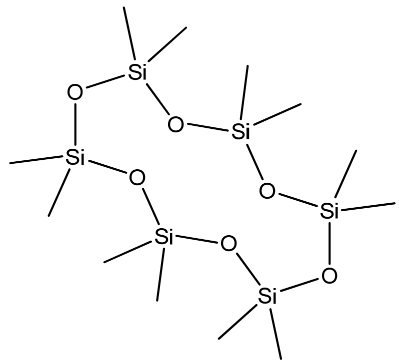
Schaeffer VH, Bhooshan B, Chen SB, Sonenthal JS, Hodgson AT. 1996. Characterization of volatile organic chemical emissions from carpet cushions. J Air Waste Manag Assoc. 46:813-20.

U.S. Environmental Protection Agency (U.S. EPA). 1987. Broad Scan Analysis of the FY82 National Human Adipose Tissue Survey Specimens. EPA-560/5-86-035, December 1986; Characterization of HRGC/MS Unidentified Peaks from the Analysis of Human Adipose Tissue. EPA-560/5-87-002A, May.

U.S. Environmental Protection Agency (U.S. EPA). 1992. Thirtieth report of the Interagency Agency Testing committee to the Administrator, receipt of report and request for comments regarding Priority Testing List of chemicals. July 9, 1992. Federal Register. 57(132):30603-30618. Available at: http://tsca-itc.syrres.com/itcrep/docs/30.pdf.

U.S. Environmental Protection Agency (U.S. EPA, 2002). Non-Confidential Inventory Update Reporting Production Volume Information. Toxic Substances Control Act (TSCA) Inventory. Available at: http://www.epa.gov/oppt/iur/tools/data/2002-vol.htm.

Dodecamethylcyclohexasiloxane (D6) [CASRN: 540-97-6]][3]



Exposure or potential exposure to the public or specific subgroups:

D6 is used in the production of consumer products and industrial products both as a raw material and as an intermediate in the production of silicone polymers. Silicone polymers are used to produce personal care products, pharmaceuticals, defoamers, surfactants, leveling agents, mold release agents, lubricants, cleaners, sealants, architectural coatings, mechanical, heat transfer and dielectric fluids, polishes and coatings. Annual U.S. production/import volume of D6 was between 10 and 50 million pounds in 2002 (U.S. EPA 2002). D6 has been detected in indoor and outdoor air (Kaj et al. 2005, Norden 2005), in drinking water (Lucas 1984), and in sewage sludge (Kaj et al. 2005, Norden 2005). Daily intake of D6 from a variety of sources was estimated by Environment Canada (2008) as ranging from 28.7 µg/kg bodyweight for persons 60 years and older to 87.0 µg/kg bodyweight for children 6 months to 4 years of age. Environment Canada (2008) estimated the upper limit of daily systemic dose of D6 from personal care products to be 100 µg/kg/body weight/day. Horii and Kannan (2008) measured the concentration of D6 in select consumer products (range 0.33 to 43,100 µg/g) and estimated daily exposure for women in the United Sates (ages 19-65) as 22,000 µg/day.

Known or suspected health effects[4]:

The liver is thought to be the target organ for oral exposures, and potentially for inhalation exposures (Environment Canada 2008). D6 exposure has been associated with liver and thyroid enlargement and reproductive effects (Dow Corning 2006). Model calculations suggest that D6 has the potential to affect aquatic organisms at concentrations close to its water solubility (Environment Canada 2008).

Potential to biomonitor:

Physical and chemical properties:

Vapor pressure 4 Pascal (0.03 mm Hg) at 25ºC.

Water solubility 0.00513 mg/L at 23ºC.

Octanol/water partition coefficient: log K_{ow} 4.36-9.06

---

[3] D6 is also contained under another CAS No. (69430-24-6) which is associated with the following names: cyclopolydimethylsiloxane, cyclopolydimethylsiloxane (DX), cyclosiloxanes di-Me, dimethylcyclopolysiloxane, polydimethyl siloxy cyclics, polydimethylcyclosiloxane, cyclomethicone and mixed cyclosiloxane (Environment Canada 2008).

[4] Summarized from 2008 Environment Canada review of D6

Bioaccumulation: Bioconcentration Factor/Bioaccumulation Factor (BAF/BCF) > 5000.
Persistence: In comparison to D4 and D5, D6 has reduced aquatic bioavailability (Environment Canada 2008). The main environmental release of D6 is to air (78 percent) where most (99 percent) of it will remain ($t_{1/2}$ 6 days); of the D6 that ends up in water ($t_{1/2}$ > 180 days), 98 percent is adsorbed to suspended solids (sediment $t_{1/2}$ > 365 days). Almost 100 percent of the D6 that is released to soil remains in soil (soil $t_{1/2}$ > 180days) (Allen et al. 1997, Environment Canada 2008). Environment Canada (2008) concluded that with a biomagnification factor (BMF) of 20, D6 is "likely to biomagnify in terrestrial food chains." It also concluded that D6 meets the criteria for persistence and bioaccumulation potential in air, water, and sediment.[5]

Past biomonitoring studies: A 1982 national survey of human adipose tissue found D6 in 28 of 46 people sampled (U.S. EPA 1987). Flassbeck et al. (2001) analyzed plasma and blood of women exposed to silicone gel filled implants (n = 14) and found that many years after the removal of ruptured silicone implants, D6 was present (17 ng/mL, ~ 17 ppb) in the plasma of one woman. D6 was not detectable in plasma or blood of women without implants. In 3 women with silicone gel-filled implants, D6 was present at levels ranging from 25.1-780 ng/g (~25-780 ppb) depending on the woman and the type of tissue sampled; no siloxanes were detected in control breast tissue samples (Flassbeck et al. 2003).

Availability of analytical methods: Method similar to those used for analyzing D4 and D5.

Availability of adequate biospecimens: Plasma and blood.

Incremental analytical cost: Can be bundled with other cyclosiloxanes.

References:

Allen RB, Kochs P, Chandra G. 1997. Industrial organic materials, their environmental entry and predicted fate. In G. Chandra, Editor, The Handbook of Environmental Chemistry, Part H: Organosilicon Materials vol. 3, Springer-Verlag, Berlin. pp. 1-25.

ARB Consumer Products Solvents Database. Available at:
http://www.arb.ca.gov/db/solvents/solvent_pages/Miscellaneous-HTML/dodecamethylcycloh.htm

Dow Corning. 2006. Combined repeated dose toxicity study with the reproductive/developmental toxicity screening test for dodecamethylcyclohexasiloxane (D6) in rats. Report No. 2006-I0000-56154. [cited in SEHSC (Silicones Environmental Health and Safety Council). 2007c. Additional toxicity and exposure information for a screening health assessment of dodecamethylcyclohexasiloxane (D6), CAS No. 540-97-6. November 13, 2007].

Environment Canada. 2008**.** Draft Screening Assessment for the Challenge Dodecamethylcyclohexasiloxane (D6) Chemical Abstracts Service Registry Number 540-97-6. Available at:
http://www.ec.gc.ca/substances/ese/eng/challenge/batch2/batch2_540-97-6_en.pdf.

Flassbeck D, Pfleiderer B, Grumping R, Hirner AV. 2001. Determination of low molecular weight silicones in plasma and blood of women after exposure to silicone breast implants by GC/MS. Anal Chem. 73(3):606-11.

Flassbeck D, Pfleiderer B, Klemens P, Heumann KG, Eltze E, Hirner AV. 2003. Determination of siloxanes, silicon, and platinum in tissues of women with silicone gel-filled implants. Anal Bioanal Chem. 375(3):356-62.

5 As set out in the 2000 Government of Canada Persistence and Bioaccumulation Regulations.

HSDB (Hazardous Substances Data Bank).Available at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Horii Y. and Kannan K. 2008. Survey of organosilicone compounds, including cyclic and linear siloxanes, in personal-care and household products. Arch Environ Contam Toxicol. 55(4):701-710.

Kaj L, Andersson J, Palm Cousins A, Remberger M, Ekheden Y, Dusan B, and Brorström-Lundén E. 2005. Results from the Swedish National Screening Programme 2004: Subreport 4:Siloxanes. IVL Swedish Environmental Research Institute.

Lucas, SV. 1984. GC/MS analysis of organics in drinking water concentrates and advanced waste treatment concentrates. Vol. 1. Analysis results for 17 drinking water and 16 advanced waste treatment and 3 process blank concentrate. EPA-600/1-84-020A. (NTIS P85-128221). Columbus, OH. Columbus Labs. Health Effects Research Laboratory.

[NILU] Norsk institutt for luftforskning. 2007. Siloxanes in the environment of the Inner Oslo fjord. Rapport 986/2007. Available at: http://www.nilu.no/data/inc/leverfil.cfm?id=23299&type=6.

Norden. 2005. Siloxanes in the Nordic Environment. TemaNord 2005:593. Nordic Council of Ministers, Copenhagen. Available at: http://www.norden.org/pub/miljo/miljo/uk/TN2005593.pdf.

OEHHA Toxicity Data Review: Decamethylcyclopentasiloxane (D5). September 13, 2007. Available at: http://www.arb.ca.gov/toxics/dryclean/oehhad5review.pdf.

RIVM (Rijksinstituut voor Volksgezondheid en Milieu). 2006. Consumer Exposure (ConsExpo) Model [Internet]. Version 4.1. The Netherlands: The National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). Available at: http://rivm.nl/en/healthanddisease/productsafety/ConsExpo.jsp#tcm:13-42840.

U.S. Environmental Protection Agency (U.S. EPA). 1987. Broad Scan Analysis of the FY82 National Human Adipose Tissue Survey Specimens. EPA-560/5-86-035, December 1986; Characterization of HRGC/MS Unidentified Peaks from the Analysis of Human Adipose Tissue. EPA-560/5-87-002A, May.

U.S. Environmental Protection Agency (U.S. EPA) 2002. Non-Confidential Inventory Update Reporting Production Volume Information. Toxic Substances Control Act (TSCA) Inventory. Available at: http://www.epa.gov/oppt/iur/tools/data/2002-vol.htm.